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SHORT COMMUNICATION

DISCUSSION ON 'THE EUROPEAN SOIL EROSION MODEL (EUROSEM): A DYNAMIC APPROACH FOR PREDICTING SEDIMENT TRANSPORT FROM FIELDS AND SMALL CATCHMENTS'

P.I.A. KINNELL
Centre for Resource and Environmental Studies, The Australian National University, Canberra, ACT 0200, Australia

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ABSTRACT

All combinations of detachment by flow or raindrops, and transport by flow, raindrop-induced flow or splash have not been fully incorporated into EUROSEM. In particular, neglecting raindrop detachment combined with raindrop-induced flow transport (RIFT) leads to underestimation of erosion under certain circumstances. An error in the manuscript is also identified. Copyright © 1999 John Wiley & Sons, Ltd.

KEY WORDS: soil erosion; modelling; raindrop detachment; rain flow

Morgan *et al.* (1998) provide a description of EUROSEM, a process-based model whose focus is the within-storm modelling of rainfall erosion. The computation of soil loss in this model is based on the numerical solution of the dynamic mass balance equation:

$$\frac{\partial(AC)}{\partial t}+\frac{\partial(QC)}{\partial x}-e(x,t)=q_s(x,t) \tag{1}$$

where C is sediment concentration ($m^3\ m^{-3}$), A is the cross-sectional area of the flow (m^2), Q is discharge ($m^3\ s^{-1}$), q_s is external input or extraction of sediment per unit length of flow ($m^3\ s^{-1}\ m^{-1}$), x is the horizontal distance (m), t is time (s) and e is the net detachment rate or rate of erosion of the bed per unit length of flow ($m^3\ s^{-1}\ m^{-1}$). The term e is defined by:

$$e = DR + DF \tag{2}$$

where DR is the rate of soil detachment by raindrop impact ($m^3\ s^{-1}\ m^{-3}$) and DF is the net rate of soil particle detachment by flow. Through consideration of Torri *et al.* (1987) and Smith *et al.* (1995), e is calculated in EUROSEM by:

$$e = [(k/\rho_s)KE\,\mathrm{e}^{-zh}] + \beta\, w\, v_s(TC - C) \tag{3}$$

where k is an index of the detachability of the soil ($g\ J^{-1}$), ρ_s is particle density, KE is the kinetic energy of the net rainfall at the ground surface ($J\ m^{-2}$), z is an exponent which varies between 0·9 and 3·0 depending on soil texture but for which a value of 2 can be used for a wide range of conditions, h is the mean depth of the water

* Correspondence to: Centre for Resource and Environmental Studies, Australian National University, Canberra, ACT 0200, Australia. Email: pkinnell@cres.anu.edu.au

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layer (m), β is a flow detachment efficiency coefficient, w is the width of flow (m), v_s is the settling velocity of the detached material in water (m s^{-1}), and TC is the transport capacity of the (unimpacted) flow expressed as a sediment concentration (m^3 m^{-3}).

Rainfall erosion involves both the detachment of particles from the surface of the soil mass and the subsequent transport of the detached particles away from the site of detachment. There are four detachment–transport modes in rainfall erosion.

1. Flow detachment–flow transport (FD–FT). Normally associated with erosion in rills, but FD–FT has been observed in sheet flow on high strength crusted surfaces (Romkens, pers. comm.). On less stable surfaces, FD–FT leads to the development of microrills in interrill areas (e.g. in experiments by Meyer and Harmon, 1989).
2. Raindrop detachment–flow transport (RD–FT). RD–FT occurs in rain-impacted flow when cohesion in the soil surface is high enough to prevent detachment by flow but not sufficient to prevent detachment by raindrops impacting the flow, and the flow shear stress or stream power is sufficient to transport detached material. RD–FT is a detachment-limited erosion system.
3. Raindrop detachment–raindrop-induced flow transport (RD–RIFT). RD–RIFT occurs in rain-impacted flow when flow shear stress or stream power is not only insufficient to detach soil material from the surface of the soil mass, but also insufficient to entrain loose soil material sitting on top of the soil surface. In RIFT, sediment transport is induced by raindrop impact lifting the loose material up into the flow and will not occur in the absence of either raindrop impact or flow (Kinnell, 1990, 1993). RD–RIFT is a transport-limited system where the transport efficiency varies with flow velocity (Kinnell, 1994). Because the critical shear stress or stream power which dictates the change between RD–FT and RD–RIFT varies with particle size and density, RD–FT can operate simultaneously with RD–RIFT. It is not uncommon for fine particles detached by RD to be transported by FT while coarser particles are transported by RIFT.
4. Raindrop detachment–splash transport (RD–ST). RD–ST is common in sheet and interrill areas prior to the development of runoff. Splash transport is highly dependent on slope gradient and decreases rapidly as the depth of water on the surface increases. RD–ST is a transport-limited system, particularly when operating on large areas. Splash may transport detached material aerially to interill or sheet flow where it may then be transported along the line of flow by RIFT and/or FT. The detachment transport systems that operate under these circumstances are RD–ST–RIFT and RD–ST–FT.

The term ‘rain-flow’ transportation (Moss *et al.,* 1979) refers to RD–FT and RD–RIFT.

Although not stated explicitly by Morgan *et al.* (1998), it is implied from their reference to Torri *et al.* (1987), and their frequent use of the term ‘splash detachment’ that Equation 3 is based on the concept that splash transports sediment detached in the surrounding area aerially to interrill/sheet flow, and that the only other source of sediment that has to be transported by interrill/sheet flow is that detached from the surface underlying the flow by FD. If so, Equation 3 operates with RD–ST–FT and FD–FT and (a) ignores the transport of splashed material by RIFT, and (b) ignores the contribution made to the sediment load by the material detached by raindrops impacting interrill/sheet flow which moves by RIFT and/or FT without being splashed aerially; there is a potential for EUROSEM to underestimate the contribution raindrop impact makes to rainfall erosion in many circumstances.

In addition to concern about the failure to consider RD–RIFT and RD–FT in the formulation of Equation 3, concern exists as to the use of values of z in the range 0·9 to 3·9 when h is, as indicated by Morgan *et al.* (1998), expressed in metres. The term e^{-zh} is a coefficient that decreases from 1·0 as flow depth increases from zero. However, when z is 2 and h is expressed in metres, the term varies from 1·0 at $h = 0$ mm, to 0·998 when $h = 1$ mm, to 0·994 when $h = 3$ mm, to 0·980 when $h = 10$ mm. Examination of the data presented by Torri *et al.* (1987) shows that these values of the term are too high and that $0{\cdot}89 < z < 3{\cdot}01$ applies when h is expressed in millimetres.

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